State Of The Art of Electronic Load Controller of Self- Excited Asynchronous Generator Used In Mini / Micro Hydro Power Generation

K. Subramanian*, K. K. Ray*, K. Hari Prasad, Nand Gopal.E, Nimisha Gupta, Nirupama.V, Pragyajha and Meenakshi Sinha
*Power Electronics Division, School of Electrical Engineering
VIT University
Vellore, Tamil Nadu, India, 632 014
[1]Email id: ksubramanian@vit.ac.in

***Abstract*— This paper describes the perception of the load controller of a self-excited asynchronous generator with constant power generation. Different load controller has been reviewed. A simulation study of a simple electronic load controller was done using MATLAB/Simulink software. Performances of an asynchronous generator with electronic load controller have been evaluated. Discussions have been done over the simulation results.**

***Index Terms*—first term, second term, third term, fourth term, fifth term, sixth term**

I. Introduction

At present scenario, to decentralize the power generation system attempt has been in generating small power and distributing it locally. This prompted the use of the wind and solar energy to cope with energy crises. In such areas, Self excited asynchronous generator (SEAG) has emerged as a possible solution because of its low cost, less maintenance, brushless construction etc [1]-[3]. However, it requires a suitable controller to regulate the voltage due to variation of consumer loads.

Since SEAG has poor voltage regulation [4]–[5] it requires a suitable voltage controller to regulate the voltage due to variation of consumer loads. From the characteristics of an SEAG voltage generation, it is essential to have a load balancer at the machine terminals to maintain constant voltage for constant power operation.

A terminal impedance controller of an asynchronous generator has been developed in 1990's there after it has been modified by different authors. The aim of this work is to list out the controller development and also to study the performances of SEAG with a simple electronic load controller for a mini / micro hydro power generations using MAT LAB / Simulink software.

II. Asynchronous generator

Asynchronous generator shown in Fig. 1 is basically an induction machine, if its rotor is driven by prime mover above the synchronous speed ($N_s = \frac{120 \times f}{p}$) with sufficient capacitor bank is connected in the stator winding it can generate voltage. Here the prime mover characteristic is calibrated with a separately excited direct current motor characteristic and used as a prime mover of this asynchronous motor.

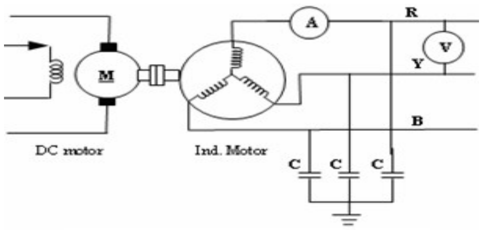


Fig. 1 Schematic arrangement of proposed asynchronous generator

III. Voltage Controller

A. Contoller Concept

The induction generator is a source of real power and absorbs reactive power while most system loads absorb real and reactive power. Grid independent self-excited asynchronous generators exhibit poor voltage regulation of mini / micro Hydel applications. Since the mechanical input remains constant, single power point operation of SEAG is made use of. The capacitor excitation of SEAG is fixed such that it gives rated output at rated speed and
the load connected is controlled such that the SEIG always sees a constant load at its terminals.

B. Asynchronous Generator Controller

Professor N. P. A. Smith [6] developed a new voltage regulator based on the intrinsic characteristics of the turbine and induction machine for mini/micro–hydro power generation system. He had been implemented the voltage controller using phase angle control technique, switched binary–weighted loads and variable mark-space ratio. The same technique is

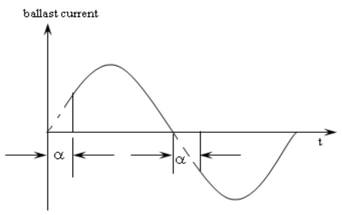
DOI: 01.ijcsi.01.01.05

reproduced to understand basic concept of the load balancer is shown in Fig. 2.

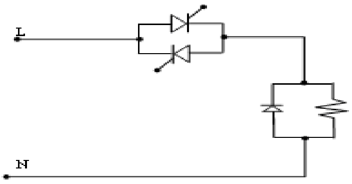
In phase angle control, the power dissipation in the ballast is varied by controlling the delay angle. Phase angle control is often used with synchronous generators but is less appropriate for induction generators, because of the variable lagging power factor produced as a result of the ballast current lagging the voltage. This increases the frequency variation already present due to lagging power factor main loads.

Binary-weighted controllers switch in fixed steps of resistance. They have the advantage of producing unity power factor ballast and they do not cause any waveform distortion. The main disadvantage of binary weighted controllers for micro-hydro schemes is the complexity resulting from using a number of ballast loads, each with its connections, wires and switching device.

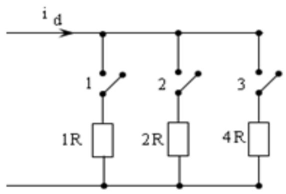
A variable mark-space ratio chopping produces a variable unity power factor load with just single ballast.



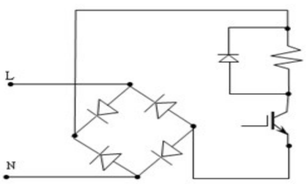
(a) Ballast current wave form for a phase angle controller



(b) Ballast controller



(c) Binary weighted load



(d)Basic switching circuit for single phase mark-space ratio

Fig. 2 (a), (b), (c) & (d) Load controller basic circuit

III. Load Controllers

The voltage and frequency is controlled separately by means of a voltage controller and an electronic load controller in a synchronous generator. But in case of an induction machine it not possible so electronic load controller to compensate the variations in the main load by automatically varying the amount of power dissipated in a resistive load, known as the 'ballast' load, in order to keep the total load constant.

A. Terminal Impedance Controller

R. Bonert and S. Rajakaruna [7]-[8] developed a load controller using controlled converter and d.c chopper is shown in Fig. 3. It regulates voltage and frequency by balancing the amount of real and reactive power either produced or absorbed. In this controller both phase control and mark-space ration control techniques are used.

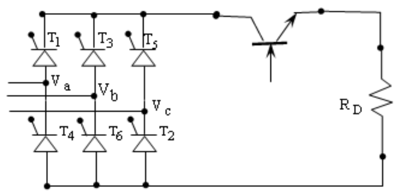


Fig. 3 Impedance controller

B . Generalised impedance Controller

J. K. Chatterjee, B. Venkatesa Permual and Naveen Reddy Gopu [9] modify the terminal impedance controller shown in Fig, 4 using voltage source pulse width -modulated bidirectional inverter with d.c battery source. The modulation index and phase angle control techniques are used to control the effective impedance of the system.

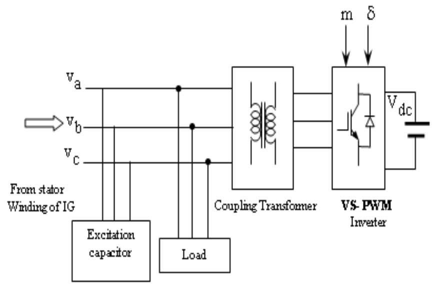


Fig. 4 Generalized impedance controller

C. Electronic Load Controller

S. S. Murthy et al [11] developed the un- controlled rectifier and d.c chopper based electronic load controller shown in Fig. 5. Even though it does not produced or absorb the any types of Var injected or taken away from the system. However mark-space ratio control technique is used to control the power balances in the system and dump load resistor (R_D).

DOI: 01.ijcsi.01.01.05

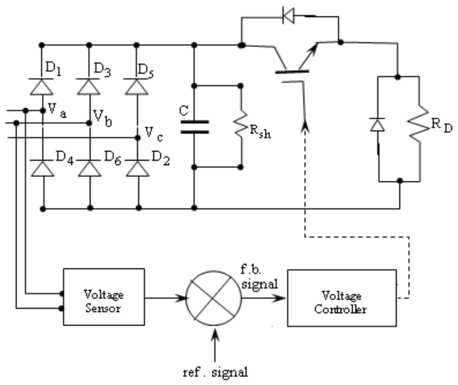


Fig. 5 Electronic load controller

Design, analyses and implementation of the electronic load controller has been done by Bhim Singh et al [12]-[14]. The same team also modifies the electronic load controller and also implemented in different configuration of the self-excited induction generator stator connections like star, delta, and star with and without neutral connections. Fig. 6 depicted the modified electronic load controller.

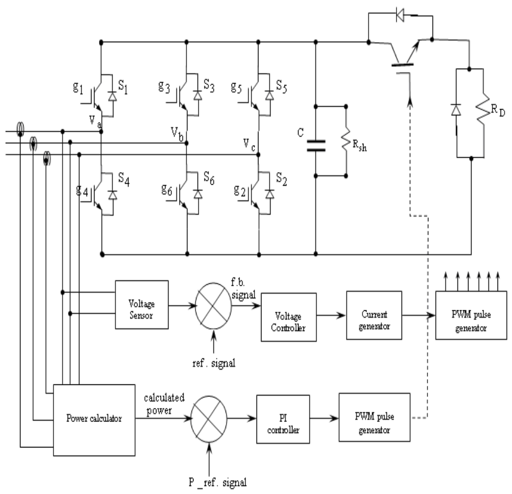


Fig. 6 Modified electronic load controller

D. AC/DC/AC converter based Impedance controller

A new load controller shown in Fig. 6 was developed using AC/DC/AC converter by the authors [15]-[18]. A change in the RLC series circuit behaviors can changes the system effective impedances. By changing the inverter frequency below the resonance frequency of the current passing through the series RLC circuit can reduce the input power factor. This seems to be the leading Var injection (or addition of external capacitor) into the system. Even though it balances the load power it can't import the power into the system because the frond end converter is a unidirectional switch. Hence the control range is limited by the components ratings.

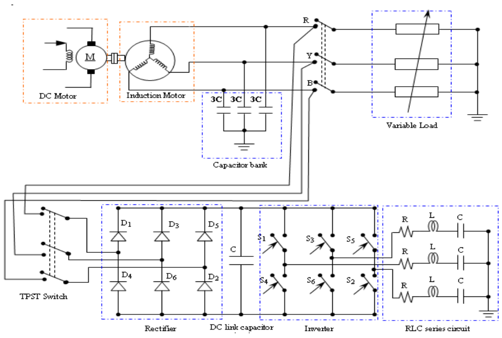


Fig. 6 Power electronic based load controller

IV. Simulation

The simulation studies on performances of SEAG have been done with simple electronic load controller shown in Fig. 5. Since the controller cost and logic of control is made easy in simple electronic load controller for Pico/ micro/mini power generator. Fig.7 depicted the simulation block diagram. The machine details and data are shown in table-1.

TABLE 1
MACHINE PARAMETERS

Voltage	415
Power	2.2.kW
Frequency	50
Stator resistance	0.0758 p.u
Stator inductance	0.0924 p.u
Rotor resistance	0.075 p.u
Rotor inductance	0.09 p.u
Mutual inductance	1.5
Inertia constant	0.044
Friction factor	0.01
Pairs of pole	2

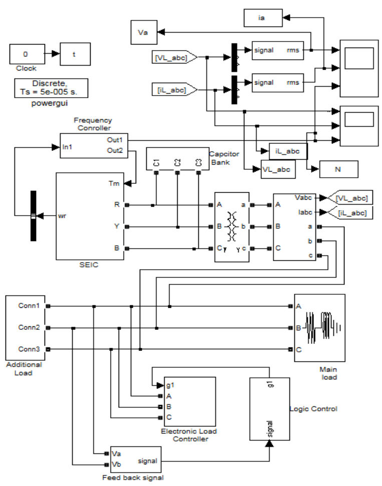
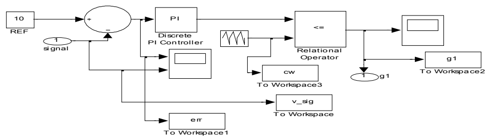


Fig. 7 Simulation model of SEASG with ELC

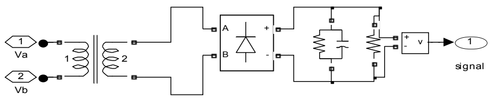
DOI: 01.ijcsi.01.01.05

V. Result

Simulation was carried out with ode 23 stiff solvers for one second using power system tools in .MATLAB / Simulink 7.2 version. Closed loop control (shown in Fig.8 (a) & (b)) has been developed.



8 (a)



(b)

Fig. 8 Closed loop control circuit and feed back signal generation

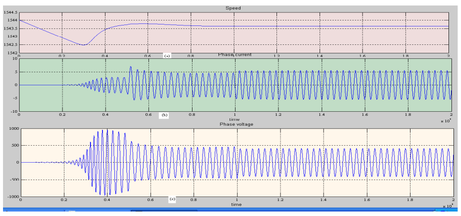


Fig. 9Simulation result of SEASG with out electronic load controller

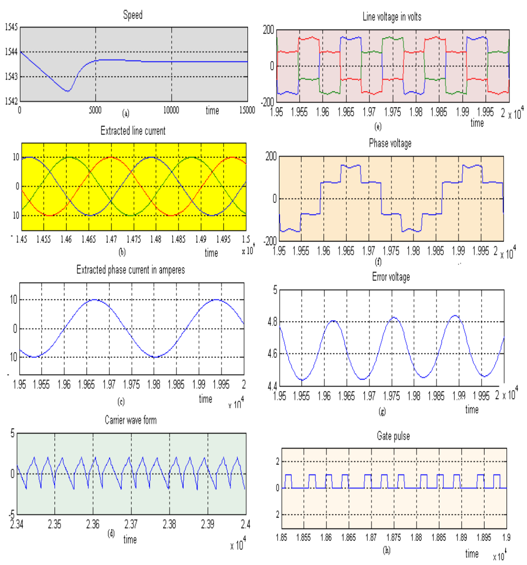


Fig. 10 Simulation results of SEASG with Electronic load controller

Fig. 9 illustrates the performance of SEASG without electronic load controller. Initially the rotor speed is 1544 rpm (shown in Fig. 9(a) at thereafter it reduced to 1525 rpm. It should be settled at 1540 rpm in .85 seconds finally. The R, L load is connected to the machine terminals at 0.4s and an additional load also connected to the system at 0.8s. The corresponding load currents and load voltages are shown in Fig. 9(b) and Fig. 9(c) respectively. The performances of SEAG with electronic controller (closed loop control) are shown in Fig. 10. The output voltage and current wave forms are shown in Fig. 10(b), Fig.10(c), Fig.10 (e) & Fig.10 (f) in closed loop control feed back signal is taken from the voltage sensing unit also converted into its absolute values. It is compared with the reference signal (constant value of 10 refers the full load power). The error signal is gained with PI controller of the gain 0.1(both k_p & k_i). The out put of the Pi controller is compared with the ramp signal of frequency 600Hz is shown in Fig. 10(d) (switching frequency of d.c chopper) and the gate signals(shown in Fig. 10(h)) is generated.

VI. Conclusion

Asynchronous generator is the best choice among the other generators for electrification of remote area like hills. It is adequate to generate a Pico/micro/mini power and also suitable generation with constant head hydro power generation. But a simple voltage regulator is necessary to regulate the voltage. Electronic load controller (uncontrolled rectifier with d.c chopper) is sufficient even though it does not support the leading Var, because most of the lighting systems are inductive(less number) and resistive network.

Acknowledgment

The authors acknowledge the management of Vellore Institute of Technology University, Vellore, India, 632014 for their support and keen interest in promoting the research and development in the Power Electronics Division by providing all the required facilities and resources.

References

[1] C. F. Wanger, “Self-Excitation Of Induction Motors,” AIEE Trans., vol. 58, pp. 47–51, 1939.

[2] S. S. Murthy, O. P. Malik, and A. K. Tandon, “Analysis of self excited induction generator,” Proc. Inst. Elect. Eng. C, vol. 129, no. 6, pp. 260–265, Nov. 1982

[3] G. Raina and O. P. Malik, “Wind Energy Conversion Using A Self-Excited Induction Generator,” IEEE Trans. Power App. Syst., vol. PAS -102, no. 12, pp. 3933–3936, Dec. 1983.

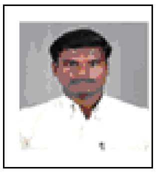
[4] J.K.Chatterjee, B.M. Doshi and K.K.Ray, “ A New method for thyristor phase controlled Var compensator”, IEEE/PES winter meeting 89.WM 133 – OPWRS, New Yark, 1989.

[5] K. K. Ray, “ Performance Evaluation of A Novel Var Controller And Its Application In Brushless Stand Alone Power Generation,” Ph.D. Thesis, department of Electrical Engineering, IIT Delhi, India,1990.

[6] N. P. A. Smith, “ Induction Generators For Stand Alone Micro – Hydro Systems”, IEEE proceeding, of International conference on Power Electronics,drives and

DOI: 01.ijcsi.01.01.05

Energy System For Industrial Growth, 1996 pp 669 – 673.
[7] R. Bonert and S. Rajakaruna, "Self-Excited Induction Generator with Excellent Voltage and Frequency Control", IEE Proceeding -Generation, Transmission & Distribution, Vol. 145, No. I. January I998, pp 31 -39.
[8] R. Bonert and G. Hoops, "Stand Alone Induction Generator with Terminal Impedance Controller And No Turbine Controls", The LEEE Energy Development and Power Generation Committee of the IEEE Power Engineering Society for presentation at the IEEE/PES 1989 Summer Meeting, Long Beach, California, July 9 - 14, 1989. pp 28 -32.
[9] S. S. Murthy, Bhim Singh, Ashish Kulkarni, R. Sivarajan and Sushma Gupta,"Field Eperiences on A Novel Pico – Hydel System using Self-Excited Induction Generator and Electronic load controller" IEEE proceeding, pp 842 – 847.
[10] Bhim Singh, S. S. Murthy and Sushma Gupta, "Analysis and Design of Electronic Load Controller for Self-Excited Induction Generators" IEEE Transactions on Energy Conversion, Vol. 21, No. 1, March 2006, pp 285 – 293.
[11] Bhim Singh, S. S. Murthy and Sushma Gupta, "Transient Analysis of Self-Excited Induction Generator with Electronic Load Controller ELC) Supplying Static and Dynamic Loads", IEEE Transactions on Industry Applications, Vol. 41, No. 5, September/October 2005
[12] Bhim Singh, S. S. Murthy and Sushma Gupta, "An Improved Electronic Load Controller for Self-Excited Induction Generator in Micro-Hydel Applications", IEE proceeding 2003, pp 2741 -2746.
[13] S. S. Murthy, Rini jose and Bhim Singh, "A practical load controller for stand alone small hydro system using Self-Excited Induction Generator", IEEE Proceeding 1998 pp 359 – 364.
[14] Subramanian Kulandhaivelu and Ray K.K. "Investigation On Loading Effect of a Series Resonance Circuit on Asynchronous Generator With AC-DC-AC Converter as a Load Balancer" Proceeding of 2nd International conference on Emerging Trends in Engineering & Technology (ICETET-09), Published in IEEE Explore, 16 -18th December, 2009, Nagpur, log. No 978-0-7695-3884-6/09 $26.00 © 2009 IEEE pp 453 - 458.
[15] Subramanian Kulandhaivelu and Ray K.K. "Loading Effect of a Series Resonance Circuit on Asynchronous Generator in an isolated Power Generation" Proceeding of International conference on Advances in Computing Control and Telecommunication Technologies, ACT 2009, Published in IEEE Explore, , 28 -29th December, 2009, Kerala, , log. No 978-0-7695-3915-7/09 $26.00 © 2009 IEEE DOI 10.1109/ACT.2009,47 pp 156 -158.
[16] K. Subramanian and K.K Ray. "Experimental studies of loading Effect of a Series Resonance Circuit on an Asynchronous Generator in an isolated Power System" Proceeding of International conference on Recent Advancements in Electrical Sciences (ICRAES'10) organized by department of Electrical and Electronics Engineering and Electronics Communication Engineering, K.S.R college of Engineering, Tiruchengode, Tamil Nadu, 8 & 9th January, 2010, pp 47-59.
[17] K. Subramanian and K.K. Ray, "Modeling and Simulation of an Asynchronous Generator with AC/DC/AC Converter Fed RLC series Circuit in an Isolated Power generation System", Proceeding of International conference on Recent Trends in Information, Telecommunication and Computing , ITC 2010, Published in IEEE Explore, , 28 -29th December, 2009, Kerala, , log. No 978-0-7695-3975-1/10 $25.00 © 2010 IEEE DOI 10.1109/ITC.2010.60,pp 80-84.
[18] Mat Lab software package.



K. Subramanian

He received B.E degree in Electrical and Electronics Engineering and M.E degree in Power System from National Institute of Technology (Formerly Regional Engineering College), Thiruchirappalli-15 in 1994 and 1998. His research interest is Induction generator, Electrical Machines, Modeling & Simulation, Power Electronics applications in Reactive Power Control.

K. K. Ray

He obtained his B.E degree in Electrical and Electronics Engineering from Jadavpur University, M.Tech degree in Solid State Control from IIT, Kanpur and Ph.D from IIT, Delhi. Former Professor Indian School of Mines, Presently senior Professor, VIT University, India, His area of Interest is Power Electronics Electrical Machines and Reactive power Control

K. Hari Prasad

He received B.Tech degree in Electronics and Instrumentation Engineering from Sreenivasa Institute of Technology and Management Studies, Andhra Pradesh in 2007. He is currently pursuing Master of Technology in Power Electronics and Drives at Vellore Institute of Technology University, Vellore, India. His area of interest is Induction generator, Power Electronics.

E. Nand Gopal

He is pursuing B. Tech degree in Electronics and Electronics Engineering at Vellore Institute of Technology University, Vellore, India

Nimisha Gupta

She is pursuing B. Tech degree in Electronics and Electronics Engineering at Vellore Institute of Technology University, Vellore, India

Nirupama. V

She is pursuing B. Tech degree in Electronics and Electronics Engineering at Vellore Institute of Technology University, Vellore, India

Pragya Jha

She is pursuing B. Tech degree in Electronics and Electronics Engineering at Vellore Institute of Technology University, Vellore, India

Meenakshi Sinha

She is pursuing B. Tech degree in Electronics and Electronics Engineering at Vellore Institute of Technology University, Vellore, India

DOI: 01.ijcsi.01.01.05